

# ADA 084248

RADC-TR-80-11 Phase Report February 1980





### TERRAIN SCATTER PARAMETER MODEL

ITT Research Institute

J. T. Cochrane, Jr.

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
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#### TABLE OF CONTENTS

Subsect	ion			Pag
BACKGRO	UND	• • • • • •	• • • • • • • •	1
OBJECTI	VES	• • • • •	• • • • • • • •	2
ANALYSI	5	• • • • • •	• • • • • • • •	2
Desig	n	• • • • • •	• • • • • • • •	2
Progra	amming	• • • • • •	• • • • • • • •	3
RESULTS	• • • • • • • • • • • • • • • • • • • •	• • • • • •	• • • • • • • •	6
	LIST OF TABLES			
Table				
1	GEOLOGIC CODES	• • • • • •		3
2	RECORD FORMAT FOR RADC/EEC MAGNETIC	TAPE	• • • • • • • •	4
3	SITE LOCATIONS AND CELL DIMENSIONS	• • • • • •	• • • • • • • •	5
	LIST OF APPENDIXES	S		
Appendi:	<u>K</u> ·			
A	EQUATIONS FOR COMPUTER MODEL	• • • • • •		9
В	GENERAL LOGIC FLOW FOR COMPUTER MODE	L	• • • • • • • •	13
C	SPECIAL GEOLOGIC CODES FOR MASSACHUSET	TS	Consulter	19
				B
		3 .	40 1 40 d 40 m	
				1.1
	iii	<u>A</u>		. s. a*

#### **EVALUATION**

The detection of low flying aircraft is complicated by multipath signals associated with the terrain over which the target is flying.

Computer programs are being developed to analyze these complex radar returns. These programs need statistical characterizations of terrain as inputs to the calculation of the diffuse and specular reflections appropriate to the surface features in the vicinity of the radar. This present study is designed to accomplish tasks related to these calculations. The first aspect is to provide the pertinent statistical characterization for a test region where experimental data is available, so that the basic multipath formulations can be verified. Secondly the study provides the statistical description of a broad data base appropriate to operational conditions. This represents initial data needed to apply the multipath calculations to radars operating at typical site locations.

OHN F. LENNON
Project Engineer

#### TERRAIN SCATTER PARAMETER MODEL

#### BACKGROUND

The Electromagnetic Systems Concepts Branch of the Rome Air

Development Center (RADC/EEC) is investigating the detection of low

flying targets by ground-based radar systems. As part of this effort,

RADC/EEC has developed an automated capability to estimate the effects

of specular and diffuse terrain scatter, diffraction, and terrain

shielding. This capability relies on a data base comprised of

statistical parameters characterizing terrain features rather than the
actual terrain elevations.

RADC/EEC has selected one of the SEEK FROST sites to test this model. SEEK FROST is a project to replace and update the Distant Early Warning (DEW) line across Canada; this project is the responsibility of the Electronic Systems Division of the U.S. Air Force Systems Command. Currently, the Electromagnetic Compatibility Analysis Center (ECAC) is performing electromagnetic compatibility analyses for this project and has acquired the digitized topographic elevation data of the area for these analyses. Consequently, ECAC was requested to develop the computer software necessary to build the specialized data base needed by RADC/EEC. This data base was then produced by ECAC for the site chosen by RADC/EEC.

Tushoph, F. H., <u>Seek Frost EMC Analysis for FY78-79</u>, Project Plan, ECAC, Annapolis, MD, November 1977.

#### **OBJECTIVES**

The objectives of this project were:

- 1. To develop computer software which would produce a statistically characterized terrain data base according to specifications of the RADC Electromagnetic Systems Concepts Branch's terrain scatter prediction model.
- 2. To produce a data base for a typical SEEK FROST radar site chosen by the RADC Electromagnetic Systems Concepts Branch.

#### ANALYSIS

#### Design

The general scheme to produce the data base required by RADC/EEC was to first designate a rectangular area around the desired site. This area was subdivided into square cells, each with sides of about 2 km in length. A 10-by-10 array of topographic elevations was extracted within each cell. The cell dimensions and array size were specified by RADC/EEC. The array of elevations was used to calculate the statistical parameters required by the RADC/EEC analysis model.

A geologic feature code was also applied to each cell. Since ECAC's terrain data base does not contain geologic information, this data was manually extracted and, subsequently, stored on the computer. Defense Mapping Agency and Department of Mines and Technical Surveys (Canada) maps at 1:250,000 scale size were used for this extraction. TABLE 1 shows the geologic codes used.

TABLE 1
GEOLOGIC CODES

01	Airport	13	Lake
02	Beach (raised)	14	Loam
03	Bog (Palsa)	15	Moraine
04	Cleared Area	16	Pingo
05	Esker	17	Rock
06	Fiord	18	Sand
07	Foreshore Flat	19	Sea
08	Glacier	20	Swamp
09	Gravel Pit	21	Town
10	Ice Cap	22	Tundra .
11	Ice Field	23	Village
12	Intermittent Lake	24	Wooded Area

All the information for the cells was written onto magnetic tape in a format suitable for transmittal to the RADC/EEC CDC 6600 computer.

TABLE 2 provides the record format used for the project.

To evaluate this planned scheme and to provide RADC/EEC with a preliminary test data base, a small site in Northern Massachusetts was analyzed before the larger SEEK FROST production site. RADC/EEC chose this test site because terrain scatter measurements were available for the area.

#### Programming

A computer program was developed based on the general design previously discussed. Equations supplied by RADC/EEC were used in this

TABLE 2

RECORD FORMAT FOR

RADC/EEC MAGNETIC TAPE

Word	Description	Units	Format
1	"X" distance from the center of the SW corner cell to the center of this cell	meters	integer
2	"Y" distance from the center of the SW corner cell to the center of this cell	meters	integer
3	Geologic code of this cell		integer
4	Mean elevation in this cell	meters	exponential
5	Variance of elevations in this cell	meters <sup>2</sup>	exponential
6	Correlation length of elevations in this cell	meters	exponential
7	Distribution type (if negative, a Gaussian; otherwise exponential)		exponential

<sup>&</sup>lt;sup>a</sup>The distribution type will be 0 if the variance is 0 or the correlation length is greater than 2000.

program to determine mean elevation, variance, correlation length, and distribution type (either exponential or Gaussian) from each cell's elevation array. APPENDIX A provides a detailed discussion of these equations.

In the program, each cell was formed based on the available terrain. data for the area being studied. In Canada, at the SEEK FROST site, 3-second by 6-second data was available. This means an elevation exists

every 6 seconds-of-arc in the east-west direction and every 3 seconds-of-arc in the north-south direction. To best approximate a square of 2 km per side and maintain a 10-by-10 array of elevations, extraction of terrain data points was made every 18 seconds in the east-west direction and every 6 seconds in the north-south direction. Thus, a cell of 180-seconds by 60-seconds was produced.

For the test site in Massachusetts, 30-second data was available. That is, elevations are stored every 30 seconds-of-arc in both the north-south and east-west directions. A cell similar in size to the production site cell was used, even with this larger spaced data, to ensure a realistic test of the computer model. To produce this similar-sized cell, terrain data points were extracted every 9 seconds in the east-west direction and every 6 seconds in the north-south direction. TABLE 3 provides a breakdown of the site locations and cell dimension information.

TABLE 3
SITE LOCATIONS AND CELL DIMENSIONS

	Test Site	Production Site
Location	42°34'10" N	67°30'30" N
	71°32'30" W	63°54'00" W
Array Spacing	205. m x 185.2 m	204.6 m x 185.9 m
Extraction Spacing	9" x 6"	18" x 6"
Cell Size	2050 m x 1852 m	2046 m x 1859 m
	90" x 60"	180" x 60"
Topo Data Available	30" × 30"	3" x 6"

In addition to the magnetic tape output provided by the program, a printed list of the parameters calculated was also produced. A general logic flow for this computer program is given in APPENDIX B.

#### RESULTS

The computer program based on RADC/EEC-supplied formulas was written and tested. The test data base in Northern Massachusetts was begun, and an unanticipated problem with computer round-off error was encountered.

Specifically, the calculation of distribution type requires a matrix of 100-by-100 elements to be inverted. The available inversion technique supplied to ECAC by RADC/EEC was a Cholesky reduction formula. However, round-off error during the reduction caused unacceptable results (or computer error return, depending on the cell size used).

To overcome this problem, a Gauss-Jordan inversion routine programmed for double-precision number accuracy was substituted for the Cholesky routine. Also, a threshold value of 10<sup>-3</sup> was applied to each element in the matrix to be inverted. Elements less than the threshold were set equal to zero. This threshold value was specified by RADC/EEC. To test the accuracy of the new inversion routine and the application of the threshold, the modified matrix and its inverse were multiplied together. The resulting product produced values of less than 10<sup>-12</sup> in the off-diagonal elements.

The test data base in Massachusetts and the production data base in Canada used this inversion method. Each data base was supplied to RADC/EEC on magnetic tape with a listing of the tape's contents.

#### APPENDIX A

#### EQUATIONS FOR COMPUTER MODEL

The following equations define the statistical parameters specified by RADC/EEC for use in the project. In all equations, the term z ( $x_i$ ,  $y_j$ ) is assumed to be the terrain elevation at the point ( $x_i$ ,  $y_j$ ). For this project, the parameter N=10 was used.

MEAN HEIGHT:

$$\frac{1}{Z} = \left(\frac{1}{2}\right) \begin{bmatrix} N & N \\ E & E \\ i=1 \end{bmatrix} = \begin{bmatrix} Z & (x_i, y_j) \\ i & j \end{bmatrix}$$
(A-1)

VARIANCE:

$$V = \left(\frac{1}{\frac{1}{N}}\right) \sum_{i=1}^{N} \sum_{j=1}^{N} (Z(x_{i}, y_{j}) - Z)^{2}$$
(A-2)

CORRELATION LENGTH:

$$C_{L} = (C_{L1} + C_{L2})/2$$
 (A-3)

using

$$C_{L1} = \tau * \begin{bmatrix} N-1 & 4 & N-1 & 2 & N-1 & 2 \\ \Sigma & K / \Sigma & K & - & \Sigma & K & C \\ K=1 & K=1 & K=1 & 1 \end{bmatrix}^{1/2}$$
 (A-4)

$$C = \tau \begin{bmatrix} N-1 & 4 & N-1 & 2 & N-1 & 2 \\ \Sigma & K & / & \Sigma & K & - & \Sigma & K & C \\ K-1 & K=1 & K=1 & 2 & 2 & (K) & (1-1/e) \end{bmatrix}^{1/2}$$
 (A-5)

where

- the separation in the "Y" direction between topographic elevation points, in meters
- the separation in the "X" direction between topographic elevation points, in meters.

and

$$C_{2}(K) = \left\{ \begin{bmatrix} N & N-K \\ E & E \\ i=1 & j=1 \end{bmatrix} Z (x_{i}, y_{j}) Z (x_{i}, y_{j+K}) \right\} / N^{2}$$

$$- \begin{bmatrix} N & N-K \\ E & E \\ i=1 & j=1 \end{bmatrix} Z (x_{i}, y_{j})$$

$$+ \begin{cases} N & N-K \\ E & E \\ i=1 & j=1 \end{cases} Z (x_{i}, y_{j+K}) - ZN (N-K) \end{bmatrix} Z / N^{2}$$

$$+ \begin{cases} N & N-K \\ E & E \\ i=1 & j=1 \end{cases} Z (x_{i}, y_{j+K}) - ZN (N-K)$$

DISTRIBUTION TYPE:

$$D = Q^2 - S$$

where

$$Q^2 = (z_{(g)} - \overline{z})^T R^{-1} (z_{(g)} - \overline{z})$$

 $(z_{(g)}^{-\overline{z}})$  = the matrix developed from expanding  $z(x_i, y_j) - \overline{z}$ for all  $(x_i, y_j)$ 

R = the covariance matrix whose elements  $\rho_{ij}$  are defined:

$$\rho_{ij} = \exp(-E_{ij}^2/c_L^2)$$
 and  $E_{ij}^2 = (x_i - x_j)^2 + (y_i - y_j)^2$ 

and 
$$S = ((N + 1) + 2 \ln F) + 2 (2(N+1) \ln F)^{\frac{1}{2}}$$

$$F = \exp\left(\frac{N+1}{2}\right) F\left(\frac{N+1}{2}\right) / \sqrt{\pi} \left(\frac{N+1}{2}\right)$$

For this project, F was approximated by:

$$F = \sqrt{2} + \left(\frac{1}{6(N+1)}\right)$$

#### Appendix B

## APPENDIX B GENERAL LOGIC FLOW FOR COMPUTER MODEL

The general logic flow of the computer model developed for RADC/EEC is presented in Figure B-1.

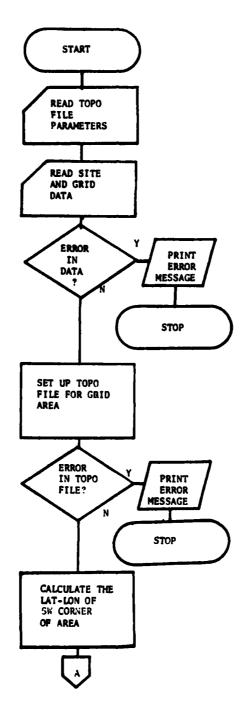
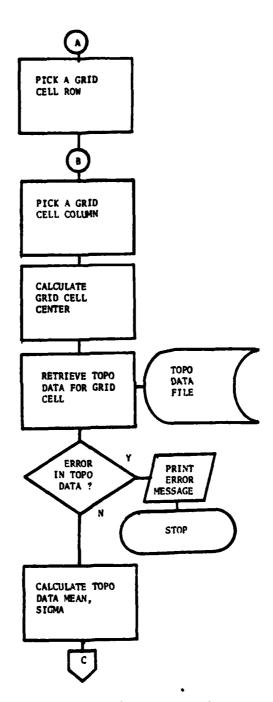


Figure B-1. General logic flow for analysis model. (Page 1 of 4).



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Figure B-1. (Page 2 of 4).

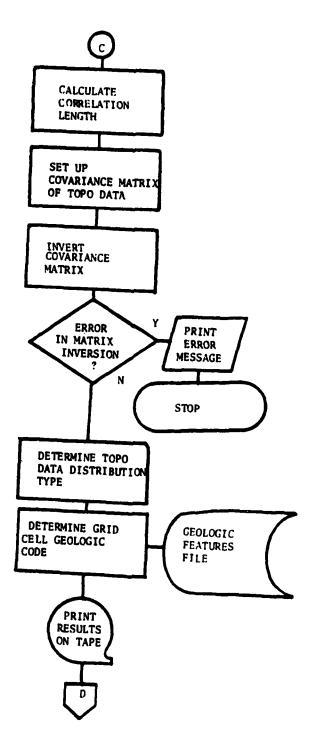


Figure B-1. (Page 3 of 4).

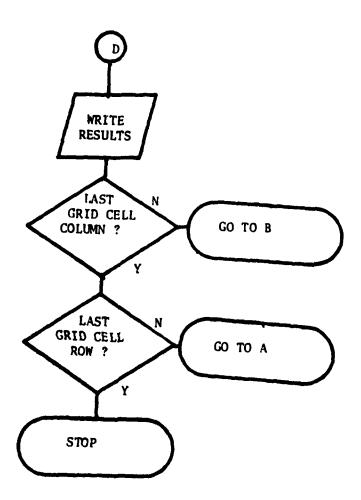


Figure B-1. (Page 4 of 4).

#### APPENDIX C

## GEOLOGIC CODES (FOR MASSACHUSETTS TEST)

- 0 Sea Water
- 1 Woods
- 2 Swamp
- 3 Lake
- 4 Cleared Area
- 5 Town (City)
- 6 Road
- 7 Intermittent LakeA

A The Massachusetts are has few true intermittent lakes. The code was used when many small lakes or ponds appear in a cell (rather than a large, all water cell).

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